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ABSTRACT

The Computer Assisted Teaching Unit (CATU) was instituted at Queen Mary College in 1973 to provide aid to the Faculty of Engineering in developing and implementing computer-based learning procedures to support the undergraduate teaching program. Earlier computer programs had simulated electrical and nuclear systems to give students the opportunity to examine the characteristics and responses of these systems, and then, as now, were complementary to lecture, tutorial, and conventional laboratory work. By 1973, there were several computer-assisted instruction (CAI) programs in use, and a teaching station concept was implemented that combined a keyboard, a printer, and a screen. The need to establish a multi-user CAI system to accommodate increasing demand coincided with a national development program in computer assisted learning (NDPCAL) which provided some financial support for the system. Survival has been influenced by the concentration of CATU on CAI in engineering, which has made it difficult to obtain general college support and additional university support. However, after 10 years of operation, the CATU laboratory is now a well-established and integral part of the educational facilities. The collaborative development of CAI materials has produced an extensive library of packages which are available to the academic community through a program exchange. Twelve references are listed. (LMM)

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A DECADE OF COMPUTER ASSISTED LEARNING

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Background

The Computer Assisted Teaching Unit (CATU) was set up at Queen Mary College in 1973 to provide a service to the Faculty of Engineering in developing and implementing computer based learning procedures to support the undergraduate teaching programme. The Faculty has an annual undergraduate intake of about 250, and is divided into departments specialising in aeronautical, civil, electrical and electronic, materials, mechanical and nuclear engineering.

There was already some activity in the uses of computers in electrical and nuclear engineering education at Queen Mary College, dating back to 1966 and arising from the enthusiasms of one or two members of the academic staff. Prior to 1973 there was no formal and very little informal support for this activity in terms of staff and resources. The computer system, a single user PDP9 with 8 kilobytes of main memory, had primarily a research role, and the number of terminal hours available for CAL was severely limited.

The pattern of activity which was to form the basis of the CATU work was already becoming evident in those early days. The first programs had been devised to meet an evident adacemic need in simulating electrical and nuclear systems to give students the opportunity to examine the characteristics and responses of these systems, which would not otherwise have been available to them. This was seen as complementary to lecture, tutorial and conventional laboratory work, and has continued to provide the rationale for CATU.

At a time when most computing provision in universities was in batch mode it was clear that the CAL environment had to be interactive. The numeric evaluations, essential for giving an appreciation of sizes and sensitivities, were computationally demanding and required appreciable processor power to ensure an acceptable response time at the terminal, which in turn was essential to hold and sustain student interest. Response time is critical in selecting a computer system for CAL and has important implications when considering the suitability of current microprocessors.

The acquisition of a graphics terminal in 1971 had greatly enhanced the impact of the early programs. The simulated systems and processes had been selected because of their complexity, either in the defining equations or in the multiplicity of input and output parameters whose variation and inter-relation was of interest. The assimilation and interpretation of the correspondingly large volume of output data demanded graphical presentation; if the computer system could not provide this then the students would be obliged to plot their own graphs by hand and, however desirable this might be in promoting a skill necessary for engineers, it was unreasonable to require it to the extent that would be involved. It was clear then that computer graphics would play a highly significant role in an expanded facility, and this has been confirmed by experience (1).

By 1973 there were four or five CAL programs in use at Queen Mary College, each providing two or three hours of interaction at the terminal. The development of new material and even the refinement of the existing material was painfully slow, depending upon the time which could be spared by the few committed academics. It has been established subsequently (2) that each hour of teaching material costs between 150 and 200 man-hours in development effort, so the lack of effective progress was hardly surprising; but it was evident, even then, that substantial staff support was needed.

It was thought necessary, from the outset, that some form of credit should attach to the CAL activity to provide an incentive for those students who were less idealistically motivated, and consequently reports were required in which results and conclusions were presented, these contributing to coursework marks. In the context of modelling and simulation this called for hard copy to be available, both of tabulated numerical output and graphical output. In the early work with the PDP9 only tabular output was available, but the need for graphical hard copy was clear.

From these considerations the concept of a teaching station emerged, combining a keyboard for data input with a printer for tabular hard copy and a screen which could display both alphanumeric and graphical information. The printer could be used to preserve a record of input data for later reference or to print selected output. The rapidity of screen display would allow the student to examine a great deal of information generated by the program before selecting and

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hard-copying the material to be included in the report. The students themselves attach considerable importance to the availability of printed material but it is necessary to impose restrictions on the quantity they can take away, to force them to be discriminating in their choice.

This specification formed the basis of selection of hardware for CATU in 1973 (3). It is perhaps of interest to note that ten years later the same broad requirements hold good, although the available hardware has changed remarkably in cost and in capability.

Setting up the CATU laboratory

The need to set up a multi-user CAL system to accommodate an increasing demand from the engineering departments at Queen Mary College coincided, happily, with a UK government decision to set up a national development programme in computer assisted learning (NDPCAL). This was a five year programme (1973-77) charged "to develop and secure the assimilation of computer assisted and computer managed learning on a regular institutional basis at reasonable cost" (4). The work in hand at Queen Mary College attracted support from NDPCAL and became the focus of a project in engineering science known as the Engineering Science (CAL) Project, which involved the collaboration of initially three and finally six institutions of higher education (5). The immediate effect at Queen Mary College was that the recurrent element in the costs of an expanded CAL facility, which had been a major obstacle to progress, became available from NDPCAL through a matched funding contract in which the capital costs of the equipment were provided by Queen Mary College. The result was the establishment, in 1973, of the Computer Assisted Teaching Unit with a 28K PDP11/40, five ASR33 teletypes and five Tektronix 4010 graphical display terminals (i.e. five teaching stations), supported by two full time staff appointments. The system was dedicated to computer based learning applications, in sharp contrast to other computing facilities in the College and University, where research had priority.

At the height of the NDPCAL project a total of nine staff were employed in the six institutions; most of their time was deveoted to program development and implementation, so that new teaching material was brought forward at a relatively rapid rate and this was reflected in the growth of activity in CATU.

Figure 1 shows that the logged use of teaching packages increased rapidly in the second half of the five year project as new material became available, and has subsequently remained fairly static with a slight upward trend. The fluctuations in recent years can be attributed to variations in student numbers, changes in curriculum and changes in an academic staff, the latter two factors resulting in some instances in the withdrawal of a particular packag from use. The established pattern must be seen against the policy in the Faculty of morning lectures,

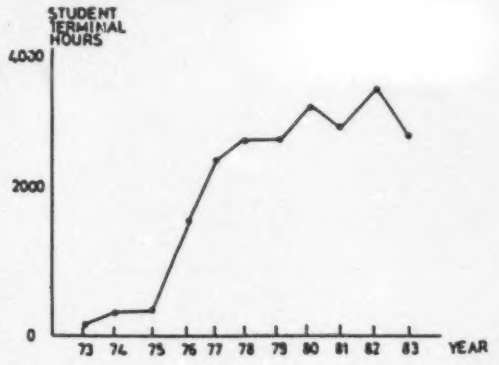

Figure 1

Annual total student terminal hours for scheduled CAL.

afternoon laboratories, with CAL in the latter category, so that a maximum capacity of the order of 4000 terminal hours is available for scheduled CAL sessions; clearly timetabling difficulties have had a significant effect in limiting further expansion.

The extent to which CATU has become an integral part of the teaching facilities of the Faculty is indicated by the growth in the number of courses which have made use of the laboratory (Figure 2).

Figure 2

Growth in the number of Faculty courses which use CATU facilities for scheduled CAL.

The Faculty offers about 100 courses so that CATU now makes a contribution to one in five. There has been a gradual acceptance that a CATU session of 2 to 3 hours providing simulated experience of an engineering system can complement the traditional laboratory experiment and, in some cases, replace it. There are many examples of engineering systems which are expensive or dangerous, where a simulation is the only possible experience available to the student. The CATU 'experiments' have slowly become embedded in the curriculum in much the same way that conventional experiments become embedded, and whilst there are associated dangers of ossification which are well known to engineers, this makes for stability and continuity in the demand for the CATU service.

The initial financial provision for equipment for CATU was only adequate for a minimal system and there has been a gradual expansion over the years to exploit the potential of the PDP 11/40; additional memory has been added in several increments to bring the capacity to the current 160 Kbytes; additional disk capacity now gives a total of 10 Mbytes; additional terminals have been added to give seven teaching stations; a switchable hard copier is now attached to the Tektronix terminals and a fast printer, linked to a spooling system, has been added. The cost of these enhancements has been met from a variety of sources, both external and internal; at no time has there been a budget allocation for equipment purchase and the case for each incremental addition has had to be argued, often at some length. It is significant that in the current financial year the CATU laboratory has for the first time been allocated a modest equipment grant.

Survival

Throughout its existence CATU has concentrated on CAL in engineering, mainly because, apart from the first few years, it has not had the capacity to offer its services to other Faculties of Queen Mary College. There is little doubt that a similar demand could be found in the Science Faculty, for instance. The management of the Unit, both administrative and technical, has been wholly in the hands of engineers, with no direct involvement of the Queen Mary College Computer Centre. This has had very specific implications for the allocation of resources, making it difficult to obtain general College support and even more difficult to obtain the additional University support which is often necessary in the federal system in London University.

Up to the end of 1978 most of the recurrent costs of CATU, including the salaries of the two staff, were met by a grant from NDPCAL. The final recommendation of the Director of NDPCAL was that the Programme should close down at the end of its five year period since, in his own somewhat optimistic words, "computer assisted learning and computer managed learning are now resilient enough to face what may be an uncomfortable couple of years" (4). This was the end of external support and meant that, for CATU to survive, the staff salaries and other recurrent costs had to be assimilated by Queen Mary College. There was certainly an uncomfortable period before that could be achieved, but achieved it was, mainly on the basis of the argument that some £250,000 had been invested in CAL in engineering by NDPCAL and that Queen Mary College must continue to exploit that investment. The two appointments were short-term, however, and have remained so, indicating a reluctance by Queen Mary College to make a long-term commitment to CAL in engineering; in the financial stringencies to come, the renewal of a two or three year appointment, far from being a trivial formality, came to require a totally disproportionate amount of justification.

Matters were to come to a head within a year or two when government funding for universities in the UK was reduced substantially and at the same time the fees charged to overseas students were dramatically increased. This combination of events produced a fall in the funds available to Queen Mary College of the order of 20%, with implications for reductions in levels of staffing, both academic and non-academic, which have still not been resolved. Posts which became vacant were left unfilled; the renewal of short-term contracts was subject to the most detailed scrutiny; the abolition of relatively "unproductive" departments was mooted.

In this atmosphere of contentious and acrimonious debate, the senior CATU post became vacant when the incumbent secured a more prestigious appointment elsewhere. This immediately focused attention on the possible abolition of CATU, which could offer an apparent saving with minimal effect upon departmental establishments. The test for survival was the strength of support within the Faculty of engineering - whether there was a consensus that the reduced number of staff posts available to the Faculty should include the CATU posts, the implication being that alternative reductions would be made within individual departments. In the event, the support was strong and without appreciable dissent, but the vulnerability of what was still seen as an educational innovation was very apparent. The eventual decision to re-appoint carried with it an implied commitment to support of the Unit, which emerged from these trials with an appreciably strengthened position.

The final hurdle concerned the computer system, which was ageing and due for replacement. A technology which had been acceptable, even exciting, in 1973 was now seen to be restrictive and profligate in demands upon programming time and effort. The Computer Board, which channels funds for research computing to the universities in the UK, had recently declared a responsibility to fund computers for teaching, and an application was made for a VAX 11/750 to replace the PDP 11/40. In London this proposal had to be approved by a university committee, where it was competing for funds designed to meet both research and teaching provision and to cater for the needs of the many university schools and institutions. A long and delicate process of justification ensued,

involving the usual preparation of cases and appearances before technical committees - a process which was near to failure on several occasions but which eventually succeeded in reaching a compromise solution in which half the cost was met by Queen Mary College from equipment grant and half by the University for Computer Board funds. The VAX is due to be installed in the autumn of 1983.

Whilst this account of the survival of CATU is to a large extent anecdotal and parochial, it does indicate the problems confronting the develcpment of a computer based learning facility in one particular univeristy, and is not atypical of UK universities generally. It also shows that, even in higher education, there is some reward for perseverance!

Software development

It is now widely recognised that the development of high quality CAL software is time-consuming and expensive and that much of the currently available software is of poor quality (6), either because it provides an inadequate interaction for the user or beacause the educational objectives are ill-defined or trivial. Very little CAL software is transferable with the result that similar routines are being coded repetitively; very little CAL software is well documented, so that modifications to meet local requirements are unduly difficult. The use of author languages does little to solve these problems, at least in the context of engineering simulations, whilst often introducing additional restrictions for the author.

NDPCAL had as an important objective the development of well-cocumented transferable CAL software and this philosophy has persisted in CATU. In the field of engineering CAL simulations, the mathematical basis of the model needs to be carefully specified and the calculation method to be explained. This is best consigned to a separate document in a section which provides the information needed by an academic who is considering the use of the programme by his students. Different teachers will adopt different approaches to the teaching of the same subject and however non-controversial the model or simulation, there should be provision for the recipient to make changes; a second section of the document provides the necessary information about programme structure, backed by comments within the program itself. A third section gives information about the student/program interaction as practiced in the originating institution, often as specified in a laboratory sheet.

The combination of program and documentation is referred to as a 'package'. The pedagogic content of a package must come from an academic who is an expert in the relevant curriculum area and who has identified a requirement to introduce CAL into that curriculum area; the process must be academic initiated. The presentation of the CAL material to the student willbe strongly dependent upon the pedagogic specification, but the detail, structure and effective organisation of the material should be the responsibility of a specialist in CAL program design. The evolution of a polished package requires a lengthy interaction between the academic and the CAL specialist. The steps in the process will be, typically:-

- initial specification by academic
- discussion and modification of specification
- initial program specification and implementation
- discussion and program modificaiton ad lib
- trial with students
- further discussion, program modification and trials
- documentation

In the tertiary sector the trials with students will be possible only at a particular point in a course, which may be given only once a year, so that the process of refining a program can be spread over several years.

In CATU the two full-time staff provide the CAL program design input, with particular emphasis upon the use of graphics. (They also maintain and operate the computer system and supervise the running of the laboratory). About half of the academics in the Faculty have been involved with CAL program specification and implementation in collaboration with CATU over the years; some are experienced programmers, others have had little experience of computing. Some bring along a well-tested algorithm which can form the calculational base for the model - in other cases the program starts from scratch. Some are readily available and co-operative - others are difficult to pin down and have to be coaxed into giving the necessary time and attention, particularly in respect of documentation, which also requires an academic input.

There are about 50 packages available and 40 packages in current use in CATU, each typically supporting a 2 to 3 hour student session. Figure 3 shows the division between departments, in respect of (a) the use of the laboratory and (b) the number of packages in use. The differing percentages for a given department in (a) and (b) reflect the different departmental group sizes.

Each package presents an engineering system or process in option-driven interactive mode, designed to give the student free and flexible access to the system parameters of interest, to allow an investigation of system responses to parametric change and to display and compare these responses, again in a free and flexible manner. The procedures to be followed are usually indicated in an associated laboratory sheet, rather than in the program itself; this makes it a simple matter to modify the procedures, in the interests of promoting educational transferability. The students will usually be expected to write an account of their experience at the terminal and tnis, with results and conclusions, is handed in

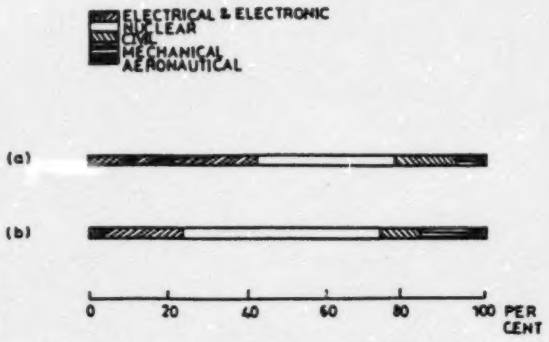

Figure 3

Division between engineering departments (1982/83)

(a) student terminal hours for scheduled CAL.
(b) number of CAL packages in use.

and marked as coursework. The procedures are, in general, an indication of areas of interest and broad objectives, leaving to the student the determination of the precise routes to be taken in using the package and setting the activity firmly in Hartley's 'discovery learning' mode (7). The aims may relate to a design objective or to the illumination of theory, to comparisons between systems, responses to parametric variations, sensitivity studies or the examination of numerical techniques and errors. Details of individual packages have been presented elsewhere (8-11); illustrative displays from representative packages are shown in figures 4 and 5. Students are usually grouped in pairs; this is not only the most popular arrangement, but also seems to promote a maximum of interaction and discussion between the students.

The CATU packages, and others in use elsewhere, are available to the academic community through a program exchange. A few new packages are brought into use each year.

Package exchange

At the end of the NDPCAL programme in December 1977 it was seen to be necessary to make the CAL software developed by the projects available to the academic community, and a number of subject based program exchanges were set up. One of these was the Engineering Science (CAL) Program Exchange (ESPE), based at Queen Mary College. Support for an initial two years was provided by the Council for Educational Technology; it was hoped (unrealistically) that the exchanges would become self-supporting by the end of that period. Subsequently ESPE has received support from the Computer Board and recently a longer-term arrangement has been made with the Numerical

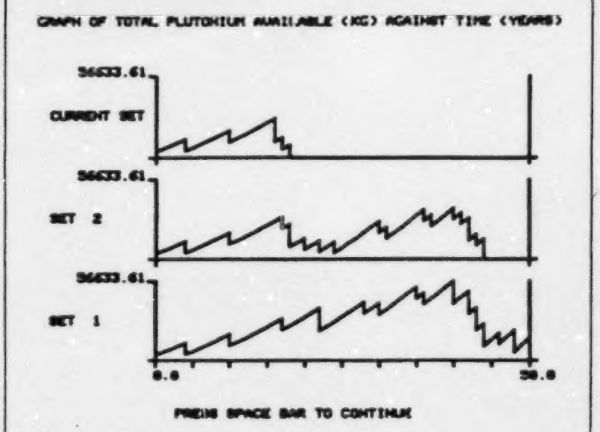

Figure 4

A display from BRECON, which examines plutonium availability in a nuclear reactor system with both breeder and converter reactor elements. The target system growth is 0.15GW(e)/year; the converter power contribution is constant, but no new converters are introduced after a specified period. The three displays show the effect of changing that period from 15 years(current set)to 17 years (set 2)and 20 years(set 1).

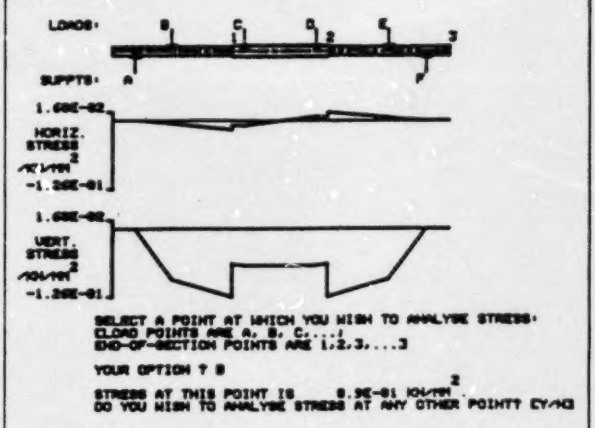
LOADS:
SUPPTS:
HORIZ. STRESS
VERT. STRESS
SELECT A POINT AT WHICH YOU WISH TO ANALYSE STRESS.
LOAD POINTS ARE A, B, C,...;
END-OF-SECTION POINTS ARE 1,2,3,...3
YOUR OPTION ? B
DO YOU WISH TO ANALYSE STRESS AT ANY OTHER POINT? CY/NO

Figure 5

A display from SHAFT, a package to design a shaft to withstand bending stresses for a given fatigue life. The shaft may have up to 14 changes in diameter and is assumed to be solid and circular. The two bearing supports may be placed at any position and up to 13 discrete forces may be applied. In addition to the stresses shown in this display, the package computes shear forces and bending moments and estimates fatigue life.

Algorithms Group (NAG), which has an international reputation as the developer and supplier of a widely implemented mathematical subroutine library.

ESPE currently offers a library of 75 packages (12), covering a wide range of topics in Aeronautical, Chemical, Civil, Electrical and Electronic, Mechanical and Nuclear Engineering and in Engineering Mathematics. Most of the programs are written in FORTRAN to the ANSI FORTRAN IV standard, and use GINO-F graphics routines. The programs average about 1000 lines of FORTRAN and are supported by comprehensive documentation, both internal and external.

Membership of the exchange is open to individuals or departments on payment of a small annual fee. Members are entitled to purchase or exchange packages, but submitted packages must conform to the programming and documentation standards adopted by ESPE. This has proved a major obstacle to the acquisition of new material from institutions other than Queen Mary College. There is little doubt that suitable material exists and is being used in other places, but the development effort required to turn a useable program into a transferable package is not readily to be found in most departments of engineering.

A package includes a machine-readable source. Paper tape was the preferred medium initially but this is rapidly following cards into limbo. Magnetic tape is universally accessible but postage costs are high. Floppy disks are still system specific. The future probably lies in direct machine to machine transfers via one of the many networks which now link our institutions.

Transfers to or between microcomputers can be technically difficult and both technical and programming aspects of transferability are liable to present problems. The future here lies in the adoption of standardised operating systems or universal intermediate languages, which are now beginning to emerge. The implementation of the ESPE packages on selected microcomputer work-stations is a long term aim and some progress is being made in this direction. For many of the packages, however, the costs of microcomputer systems having the necessary processor power and graphics capability are still high for educational applications. This may well change in the near future.

Summary

After ten years of operation and at least three major crises, the CATU laboratory is now a well established and integral part of the educational facilities at Queen Mary College. The collaborative development of computer based learning material has produced an extensive library of packages, which are available to the academic community through a program exchange. There is a continuing need for support for development, without which well documented and transferable material will emerge only slowly, if at all. The implementation of substantial engineering simulations on low cost micro-computers still presents problems but offers an exciting prospect for the future.

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